Name **Date**

HANDS-ON LAB

Hitting the Mark

A ski jumper awaits her turn at the top of a jump. She sees the landing area several meters beyond the jump on the ground below. She must land between two lines painted on the snow in order to receive a qualifying score.

Think about what ski jump designers must know in order to determine the landing area for the jumper. The ski jumper follows a projectile (arched) path through the air. The jump designers might need to estimate the jumper's initial velocity off the ramp, the time the jumper is in the air, and determine how far the jumper travels along the ground before landing. The engineer might use these motion formulas:

- Vertical distance traveled $= h = \frac{1}{2}at^2$
- Distance traveled $= \Delta x = v_i t$
- Acceleration $= a = \frac{\Delta v}{t}$

MATERIALS

- safety goggles
- desk or table
- metersticks (2)
- toy, spring-loaded, such as a dart launcher
- video-recording device, such as a cell phone

In this lab, you will determine the launch speed of a projectile and then use this value to predict where it will land when launched horizontally from some height. Can your group be the first to "hit the mark"?

RESEARCH QUESTION How can you apply the physics that you have learned to launch a ball and hit a target?

SAFETY INFORMATION

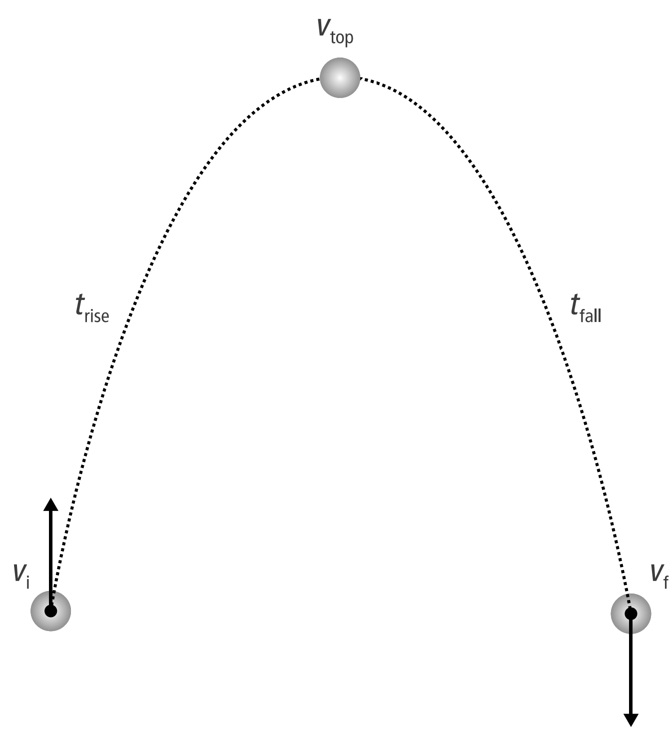
- Wear safety goggles during the setup, hands-on, and takedown segments of the activity.
- Immediately pick up any items dropped on the floor so they do not become a slip or fall hazard.
- Mark off the area where the projectile will fly. Do not allow anyone to stand in the path of the projectile.
- Wash your hands with soap and water immediately after completing this activity.

PART I: FINDING INITIAL VELOCITY

PLAN THE INVESTIGATION

1. **Figure 1** shows a ball launched vertically with an initial velocity. Think about how the time for its fall to the ground compares to the time it takes to rise to its maximum height. Also, think about how the ball's final velocity compares to its initial velocity. Use what you have learned in this lesson to explain how to find the ball's initial velocity using the height the ball rises to.

Figure 1



2. How can you measure the height a toy rises into the air? You may choose to record video of this motion to help with accuracy. Think about how you might place a meterstick within the view frame of the camera so that it can help you measure the height that the toy rises into the air. Choose whether you will hold the meterstick or secure it to a wall or table. You should also decide where to place the camera, if you choose to use one. In your Evidence Notebook, write a method to measure the maximum height the toy rises into the air.

3. Perform a trial run. Launch a spring-loaded toy projectile <u>vertically</u>, and record the height to which it rises as accurately as possible using the method you planned in Step 2. Then use the equation you wrote in Step 1 to find the initial velocity. Is the value you calculate reasonable? If not, return to your method, make adjustments, and perform another trial run. Once you calculate a reasonable value, consult with your teacher to confirm your method.

4. Prepare to collect data. Construct a data table that includes columns for trial number, maximum height, and initial velocity. Include a row to calculate the average initial velocity. If possible, use a spreadsheet to record your data and to make calculations.

CARRY OUT THE INVESTIGATION

1. Launch a spring-loaded toy projectile vertically and record the height to which it rises as accurately as possible. Complete at least three trials, but do as many as needed to obtain a consistent measure of the height. You may need to perform several different trials to ensure the consistency of your launcher's performance.

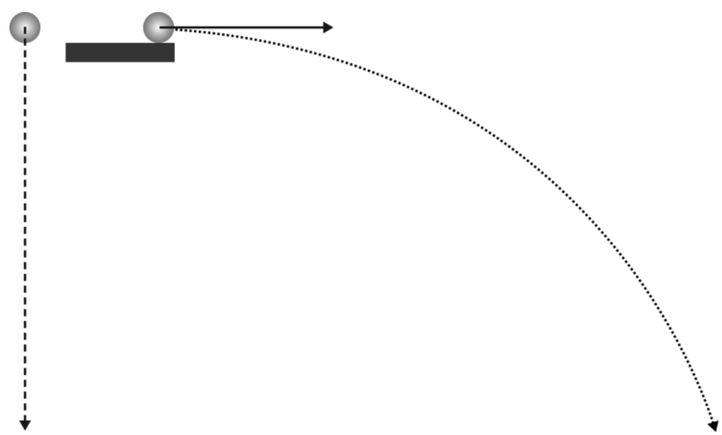
2. What is the initial velocity of your projectile? v_i = ____________________

PART II: HITTING THE MARK

PLAN THE INVESTIGATION

1. **Figure 2** presents two balls, one that is dropped and another that is launched horizontally. Think about whether or not the two balls hit the ground at the same time. Use what you have learned about projectile motion in this lesson to write an equation to find the **time** it takes the launched ball to fall to the ground.

   Figure 2

2. Since the horizontally launched ball maintains its x-velocity even while falling, how could you determine the landing location of the launched ball? Explain your thinking.

3. When you launch your spring-loaded projectile horizontally, your projectile will follow the parabolic trajectory that you have studied in this unit. What measurements do you need to predict where the toy lands?

Name **Date**

MAKE A CLAIM

Choose the surface to launch your toy horizontally from. Have your teacher approve the location. Then complete the measurements that you listed in Step 3. Use motion equations to predict where your toy lands. Show your work below.

CARRY OUT THE INVESTIGATION

1. Place a target (such as a paper plate) at the predicted landing location. Test your prediction by launching your projectile. You may try the launch three times. Mark where the toy lands, then measure the distance from this point to the base of the launching surface. Explain what happens during your tests.

2. If your toy did not hit the mark during any of the tests, evaluate what you need to change in your method to determine its landing spot. Recalculate using a corrected method and then retest your launch. Explain what happens.

ANALYZE

1. Why were you able to use the projectile's initial velocity from Part I in Part II?

2. Does the horizontal motion of a projectile depend on its vertical motion? Do you have to consider each component together or can you consider them separately?

3. Reflecting on the accuracy of your prediction, identify one to three specific sources of error. Identify which error sources were the result of errors in your measurements, then explain whether each source of error produces a predictable (systematic) effect or a random effect.

CONSTRUCT AN EXPLANATION

1. What method should a ski jump engineer use to determine the approximate landing distance of a ski jumper? What measurements would the engineer need to make? What calculations would the engineer need to perform?

2. How might air resistance affect the landing distance of the jumper? Why?

DRAW CONCLUSIONS

Write a conclusion that addresses each of the points below.

Claim How can you apply the physics you have learned to hit a target? Explain whether or not you correctly predicted where the toy projectile would land.

Evidence What evidence from the investigation supports your claims?

Reasoning Explain how the evidence you gave supports your claims. Describe in detail the connections between the evidence you cited and the arguments you are making.

EXTEND

1. Suppose you were to launch your projectile horizontally from twice the height that you used in your experiment. Would you expect it to land twice as far away? Why or why not?

2. Suppose your teacher demonstrates a new spring-loaded toy. The toy can launch a projectile from a height of 2 m so that it just touches a spot on a 3 m ceiling. How would you arrange the toy so that it fired horizontally to hit a target on the floor? In your answer include the height of the toy, the distance between the toy and the target, and your reasoning.